The Whole is not the Sum of the Parts

Masataka SUZUKI

In vision, a fundamental aspect of perceptual organization is the ability to group parts together into discrete objects and to segregate these objects from the background. This was recognized in the early 20th century by Gestalt psychologists[1-3], who investigated perceptual organization, and formulated a number of principles[4]. Works have been inherited to evolve these proposals in two respects, phenomenology and neurobiology[5]. To reconcile this dichotomy, the roles of illusions seem important. Because, they serve as a powerful window into the neurobiology of vision, and have pointed towards new experimental techniques[6,7]. Here, I introduce a set of new optical illusions, in all of which partial erasures of the visual object lead to an immediate disappearance of its whole, suggesting that the phenomena are all object-based. Critically, all stimuli (erasures) are common in that they are conductive to violate Gestalt principles for *grouping* (i.e., *closure, parallelism, good continuation and proximity)* or *figure and (-) ground segregation* embedded in the original images. These are regarded as phenomenologically explicit evidences commonly to show that the perceived whole is other than the sum of the parts[3].

The first visual target is a line drawing of a wreath composed of a stem, twigs and a circular base-frame (Fig. 1a). During fixation on a central cross, the stem is erased, leaving both of the twigs and base-frame intact (Fig. 1b). The observers reported that all of the twigs (residuals) completely disappeared immediately after the erasure time and then reappeared a few seconds later, whilst the base-frame remained visible alone all the time. This observation seems to reflect geometry of the wreath; the stem is branching into twigs continuously, while both of which abutting the base-frame at many points. According to the *good continuation* of Gestalt principles, we have a tendency to group lines or curves that follow an established direction over those defined by sharp changes in direction. This might be a cause of the selective disappearance of twigs which are grouped together with the stem as one object, while the base-frame is independent of this grouping. Similar object-based disappearances will be seen in following several demonstrations, in each of which the constituent parts of images are represented under different Gestalt principles of grouping.

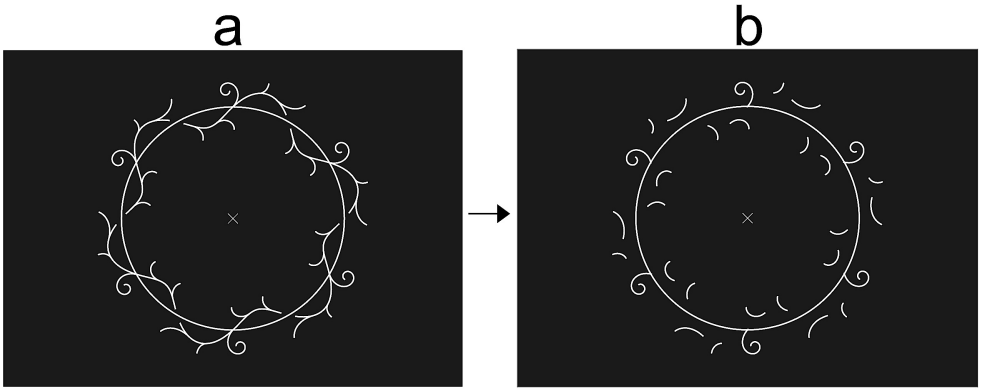

Figure 1
Physical image of wreath before (a) and after (b) removal of composite line segments
a, Original image of the wreath, which is composed of a single stem with twigs winding around a circular base-flame. Line segments depicting the stem and twigs are arranged to involve characteristic spatial pattern in term of *good continuation*. **b**, Residual image of the same wreath after partial erasure of the stem portion alone. In both panels, a circular base-frame is to confirm whether the partial erasure effect on the presence of the residuals is object- or space-selective.

The lines or curves that are parallel to each other are more related than those not parallel to each other. Figure 2a illustrates the *parallelism*, in which two wavy circles have a parallel relationship, and on both of which an open circle is superimposed to refer the resulting phenomenon to as an object-selective or space-selective. Erasure of the outer wavy circle induces the disappearance of the inner one and vice versa, while an open circle always remained visible (Fig. 2b). This suggests two wavy circles are grouped together as one object and thus the erasure of one of which induces selective disappearance of the other.

The proximity states that we perceive parts close to each other by grouping them as parts of the same object[8]. This scheme is realized in Fig. 2c, in which dots forming a wavy circle are superimposed on the more sparsely distributed random dot field, and on both of which an open circle is superimposed. When dots for both components are erased with an equal rate of 50% (Fig. 2d), the residual dots forming the wavy circle disappears leaving both of residual dots covering the random dot field and the open circle intact. The object-based grouping seems underlay the selective disappearance of dots forming the wavy circle.

According to the *closure* principle, dots (or line segments), if each of them next to each other does have continuity, are grouped together in order for the contour to be closed, and segregated from the background to interpret its whole as one object. In Fig. 2e, dots are arranged in the black background and form a wavy circle, which encloses the gray surface. Erasure of the half number of dots leads to disappearance of not only the remaining dots but the corresponding gray surface they enclose, which is filled-in with the black background (Fig. 2f). This suggests that all dots before the partial erasure are not only grouped together but segregate the corresponding surface from the background. This scheme could be a base of the simultaneous disappearance of residual dots and the surface enclosed. The same disappearance phenomenon is not observed in the

open circle superimposed on the wavy circle, which remaining visible all the time, suggesting that the phenomenon is object-selective.

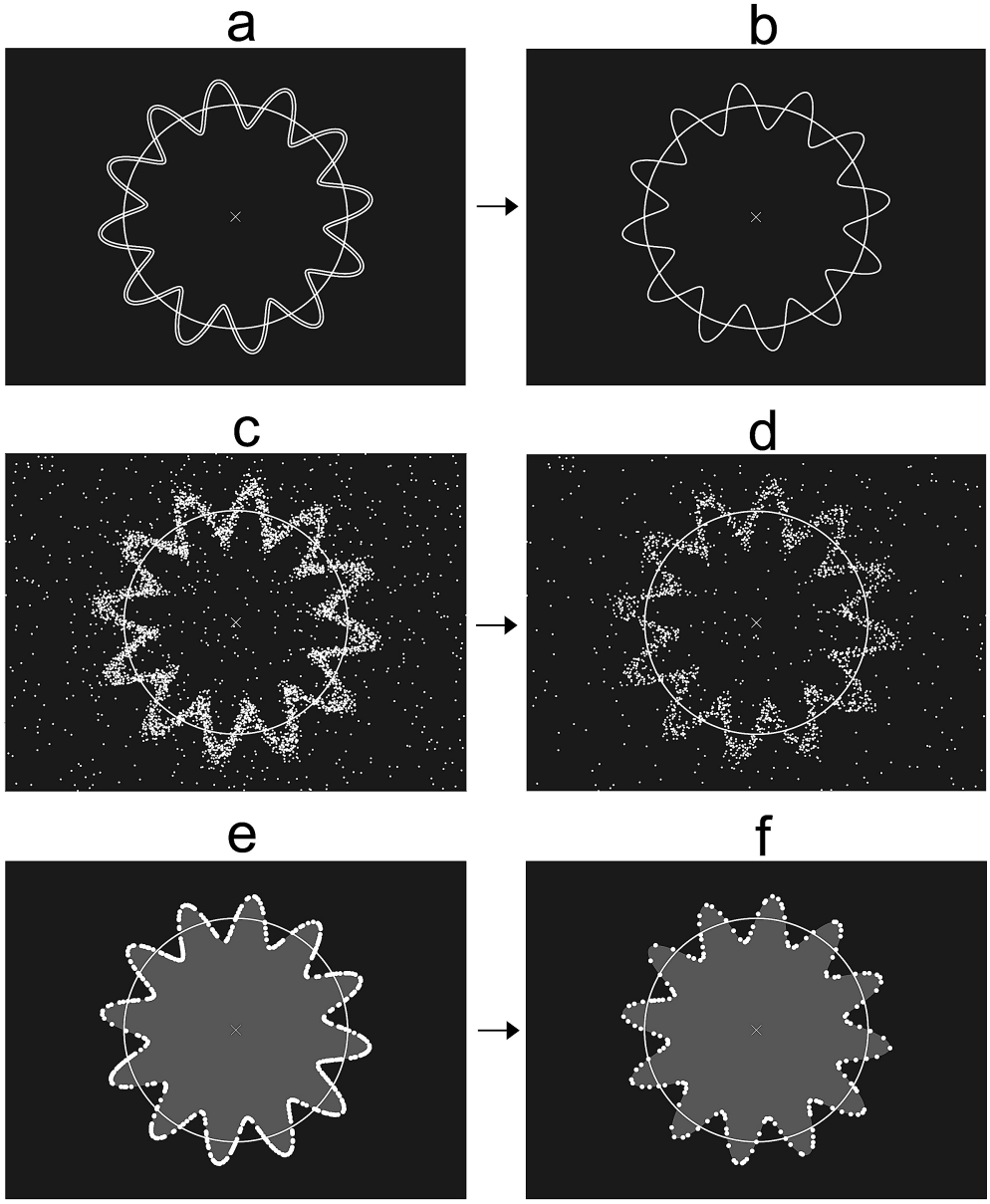

Figure 2

Partial erasure effects on object view representing *parallelism* (a,b), *proximity* (c,d) and *closure* principles (e, f)

a, *Parallelism*: two wavy circles showing a parallel relationship, on which a single open circle is superimposed. **b**, Residual image after removal of outer wavy circle in **a**. **c**, Proximity: dots grouped to form a wavy circle, superimposed on the more sparsely distributed random dot field. **d** , Residual image of two dot fields when dots for both components are erased with an equal rate of 50 % in **c**. **e**, Closure: dotted wavy circle, which encloses gray surface. **f**, Residual image after the removal of the half number of dots for the wavy circle in **e**.

Viewing images in Fig. 3a, we recognize that a gray wavy circle is superimposed on a black annulus, which vision is partially occluded by the wavy circle. This interpretation depends on two aspects of perceptual organization, *grouping* and *figure-ground segregation*. For fan-shaped black regions between concaves, a combined effect among their similarities in color, shape, as well as their continuity of inner or outer edges aligned on a circular path, would lead to *grouping* of these regions as parts of the same annulus, which parts are also seen through small circles in the convex portions of the wavy circle[9]. As for the *figure-ground segregation*, one of the basic features is that the contour separating the figure and ground belongs to the figure[2]. In Fig. 3a, the inner or outer edges of the fan-shaped, black surfaces are abutting the edge of petal-like convex of the wavy circle bi-laterally, and forming T-junctions[10] in each of these abutting regions. These can be depth cue to interpret that the boundary contours in these regions belong to the wavy surface (figure), such that the figure (wavy circle) is on top of the ground (red annulus). In this situation, when 9 black, fan-shaped surfaces are erased simultaneously (Fig. 3b), all of the residual parts for the annulus are induced to disappear in a moment, implying that 3 fan-shaped surfaces are filled-in with the background white surface and 12 holes are filled-in with gray surface of the figure (wavy circle). Accordingly, the figure remains visible alone on the blue background. These suggest strong context-dependency of all disappeared regions on what their previous surfaces are originated from. In perceptual space, all of the black surfaces are grouped together as one object, even though they are spatially separated by occlusion.

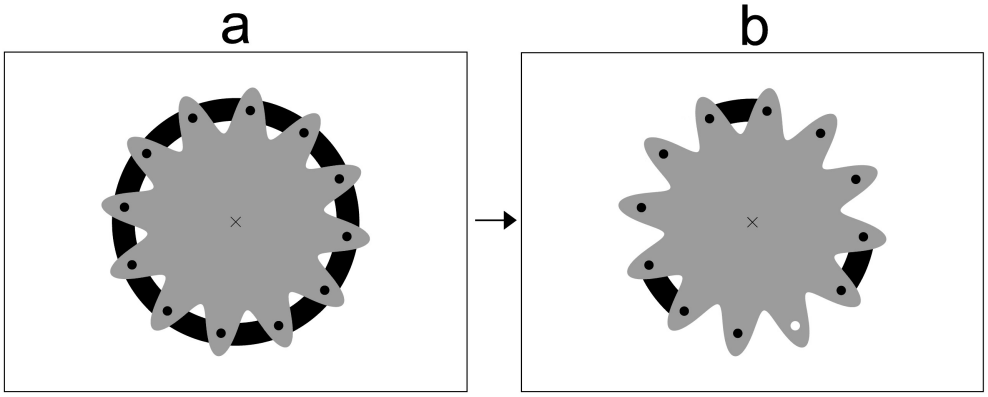

Figure 3

Partial erasure effect on surface view of object composed with spatially separated parts

a, Physical image of two overlapped surfaces before partial erasure. The figure is illustrated with a gray wavy-circle with 12 holes in the mid-portion of twelve concaves, while the ground is black annulus which parts are seen between 12 concaves of petal-like portions and through 12 holes at the mid-portion of concaves. There are 24 locations where the outer or inner edges of fan-shaped red surfaces are abutting the edges of petal-like portions of wavy circle bi-laterally. The depth relation of these abutting edges is that one forming the "roof" appears to be in front of the one forming the "stem". Thus, the contour for the surface of wavy circle owns the border ownership in these abutting regions. **b**, Residual images of two objects with half number of black fan-shaped surfaces between concaves are erased.

Overlapping surfaces are usually perceived as either figure or ground on which the figure rests. In Fig. 4b, however, we identify two overlapping surfaces (a circle and wavy circle), while their depth order seem bi-stable in that what is perceived as the figure can also be perceived as the ground and vice-versa. This is an inherent phenomenon of depth interpretation of overlapping transparent surfaces[11]. Once the line contour surrounds the wavy circle alone (Fig. 4a), however, the bi-stability stops, and we see the wavy circle on top of the white circle. Emphasis of an apparent contour for the wavy circle serves as a depth cue to interpret that the wavy circle (figure) is on top of the white circle (ground). In this situation, when the line contour of the wavy circle is erased, the corresponding surface completely disappears (Fig. 4b) (also see Figs. 2e, 2f). More surprising is the visibility of the white circle, which becomes clear as uniformly white on the light gray background. This contradicts the actual view in two respects. First, the physical color of the overlapping region is not white but light gray, similar to the background of both objects. Second, the physical color of the wavy circle outside of the white circle is not light but blackish gray. These suggest a strong context-dependency of the resulting percept of the surface on how the previous lightness of the circle is interpreted. The mechanisms which segregate the two images to represent in different layers in an object-based manner, would be needed for the independent, illusory percept of surface lightness of the overlapping surfaces12.

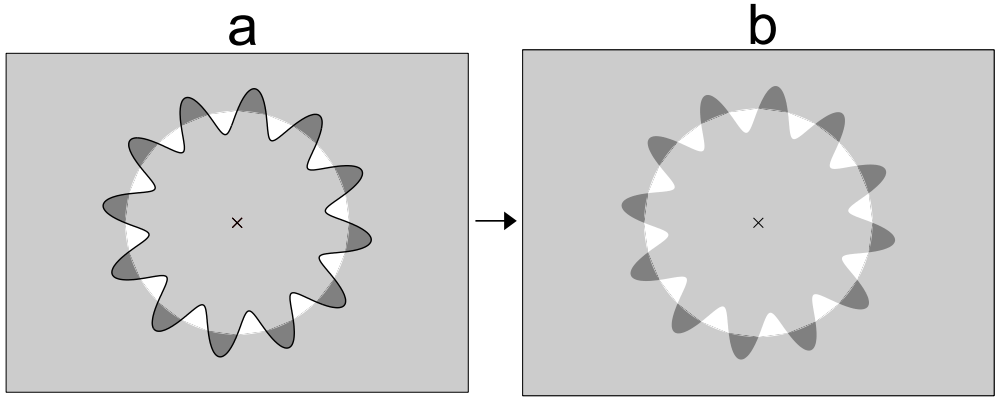

Figure 4

Contour erasure effect on figure-ground segregation of transparent surfaces

a, Physical image of a transparent overlay (wavy circle) on a white circle. The assignment of border ownership by adding a line contour to the object led to segregation of its surface as a figure (wavy circle) from the ground (circle). The figure (wavy circle) is entirely dark (blackish gray) relative to the background (light gray), as if the white circle is veiled with a dark transparent overlay. **b**, Physical images for the same two objects after removal of the line contour for the figure (wavy circle). Note the ambiguity as to which is the figure or ground in the two overlapping surfaces, and thus their depth order is undefinable. However, in a, by superimposing a line contour on the wavy circle, a "roof-stem" relationship in T-junctions formed by two surfaces become apparent, such that the edges (stems) of the white circle outside the wavy circle abutting the line contour of the wavy circle in many points. The depth ordering is thus clarified to interpret the wavy circle (figure) is in front of the white circle (ground).

A series of demonstrations show that partial removal of an object induces an immediate disappearance of residual parts of the same object, suggesting that the phenomena are object-based in all cases (Figs. 1-4). The residual parts (or surface) induced to disappear are covering quite large space (more than a 10-degree visual angle) (Fig. 1), or spatially separated from erased parts by open space (Figs. 2) or by occlusion (Fig. 3). Also, the object-based disappearances of surfaces are highly context-dependent on the manner of grouping (Fig. 3) or segregation (Fig. 2e, 2f; Fig. 4). In modern neuroscience, a substantial body of evidence suggests that conscious perception of objects depends on rapid bottom-up, implicit processes which seems to follow Gestalt principles for groupings and segregations[5], whilst top-down cognitive guidance (feedback) based on image contexts elaborates this bottom-up sequence from its beginning to the end[13-15]. Once these integrative processes are completed, the objects would be perceptually organized as one undecomposable, higher-ordered perceptual unit that we are aware of[16]. The unitary, higher-ordered representation of the object might be a basis of disintegration, leading to the disappearance of the image as a whole[17, 18]. A series of demonstrations prompt us to conceive that in the perceptual space the whole is organized as the one that is different from the sum of the parts[3].

Methods

All images used in the conditions represented in Figs. 1-4 were displayed on a color monitor (EIZO S2431W, 1920 × 1200 pixels, W518.4 × H324.0 mm) driven by a DELL Workstation (T-1700), at a refresh rate of 60 Hz. In all tasks, the image consisted of a common circle, with a diameter subtending 10.5 degrees from a central fixation point. Details of all image configurations in each of six demonstrations are described in the text or in the corresponding figure caption. All aspects of the demonstration, including stimulus generation and presentation, were carried out within the MATLAB programming environment (version 7.7) using in-house software.

The observer's head was immobilized with a chinrest located 45 cm from the computer screen. The standard procedure is the same across all image conditions. After fixating on a central cross, the observer presses a key when viewing images on the monitor. Three seconds later, some of the line segments, dots, or areas making up the object image are partially erased. Even after the erasure time, the observers were asked to keep fixation on the central cross for 3 s without blinking. After this, the observers gave verbal reports of their impressions about the residual images. During this period, the stimulus image was replaced with a black surface over the screen. The observers completed over 30 trials under each image condition.

References

1. Rubin, E. Visuell wahrgenommene Figuren. *Gyldendalske Boghandel*, Kobenhavn (1921)
2. Wertheimer, M. Untersuchungen zur Lehre von der Gestalt, II. *Psychologische Forschung* 4, 301-350 (1923).
3. Koffka, K. *Principles of Gestalt psychology*. Harcourt, Brace, & World, New York (1935).
4. Wagemans, J. et al. A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure-

ground organization. *Psychol. Bull*. 138, 1172-1217 (2012).
5. Spillmann, L. Phenomenology and neurophysiological correlations: Two approaches to perception research. *Vision Res.* 49, 1507-1521 (2009).
6. Gregory, R. L. Knowledge in perception and illusion. *Phil. Trans. R. Soc. Lond. B* 352, 1121-1128 (1997).
7. Eagleman, D. M. Visual illusions and neurobiology. *Nature Rev. Neurosci*. 2, 920-926 (2001).
8. Overvliet, K. E., Krampe, R. T. & Wagemans, J. Grouping by Proximity in Haptic Contour Detection. *PLoS ONE* 8, 1-6 (2013).
9. Nelson, R. & Palmer, E. P. Of holes and wholes: The perception of surrounded regions. *Perception* 30, 1213-1226 (2001).
10. Kellman, P. J, Guttman, S. E. & Wickens, T. D. in *From Fragments to Objects: Segmentation and Grouping in Vision.* (eds Shipley, T. F. & Kellman, P. J.) 193-245 (Elsevier Science, Netherlands, 2001).
11. Tse, P. U. Voluntary attention modulates the brightness of overlapping transparent surfaces. *Vision Res.* 45, 1095-1098 (2005).
12. Anderson, B. L. & Winawer, J. (2005) Image segmentation and lightness perception. *Nature,* 434, 79-83 (2005).
13. Murray, S. O. et al. Shape perception reduces activity in human primary visual cortex. *Proc. Natl. Acad. Sci. USA* 99, 15164-15169 (2002).
14. Connor, C. E., Brincat, S. L. & Pasupathy A. Transformation of shape information in the ventral pathway. *Curr. Opin. Neurobiol.* 17, 140-147 (2007).
15. Pomerantz, J. R. & Portillo, M. C. Grouping and emergent features in vision: Toward a theory of basic Gestalts. *J. Exp. Psychol. Human,* 37, 1331-1349 (2011).
16. Hochstein, S. & Ahissar, M. View from the Top: Hierarchies and Reverse Hierarchies in the Visual System. *Neuron,* 36, 791-804 (2002).
17. Bonneh, Y. S., Cooperman, A. and Sagi, D. Motion-induced blindness in normal observers. *Nature*, 798-801 (2001).
18. Mitroff, S. R. & Scholl, B. J. Forming and updating object representations without awareness: evidence from motion-induced blindness. *Vision Res.* 45, 961-967 (2005)